UNITED STATES PATENT APPLICATION

FOR

ADHESIVE AND SEMICONDUCTOR DEVICES

BACKGROUND OF INVENTION

This invention relates to an adhesive for bonding semiconductor chips to their attachment members (hereinafter referred to as the chip mounting component) and to semiconductor devices in which a semiconductor chip therein is bonded to its chip mounting component by the adhesive. More particularly, this invention relates to an adhesive that can bond a semiconductor chip to its chip mounting component across a constant gap and that can provide a thorough relaxation of the mechanical stresses acting on the chip. The invention additionally relates to highly reliable semiconductor devices.

Within the sphere of adhesives for bonding semiconductor chips to their chip mounting components, Japanese Laid Open (Kokai or Unexamined) Patent Application Number Hei 7-14859 (14,859/1995) teaches an adhesive that characteristically contains at least 5 weight% insulating powder consisting of at least one selection from inorganic insulators such as glasses, metal nitrides, and metal oxides that have a particle size of 50 to 100 μm. Japanese Laid Open (Kokai or Unexamined) Patent Application Number Hei 7-292343 (292,343/1995) teaches an adhesive comprising a platinum compound, spherical organic or inorganic filler having a particle size of 10 to 100 μm and a major axis-to-minor axis ratio (hereinafter referred to as the aspect ratio) of 1.0 to 1.5, an

organosilicon compound containing silicon-bonded alkoxy, organopolysiloxane containing at least 2 silicon-bonded hydrogen in each molecule, and organopolysiloxane containing at least 2 silicon-bonded alkenyl in each molecule.

The adhesives taught in Japanese Laid Open (Kokai or Unexamined) Patent Application Numbers Hei 7-14859 and Hei 7-292343, however, are not entirely satisfactory. While these adhesives can provide a constant gap or space between the semiconductor chip and its chip mounting component, they cannot provide a wide chip-to-mounting component gap and hence are unable to thoroughly relax the mechanical stresses acting on the semiconductor chip.

The inventors achieved this invention as a result of intensive investigations into the problems described above. In specific terms, an object of this invention is to provide an adhesive that can bond a semiconductor chip to its chip mounting component across a uniform gap and that can thoroughly relax the mechanical stresses acting on the semiconductor chip. Another object of this invention is to provide highly reliable semiconductor devices.

SUMMARY OF INVENTION

The adhesive of this invention is intended for the bonding of semiconductor chips to their chip mounting components and characteristically comprises a curable polymer composition that contains from 1 to 900 weight-ppm spherical filler that has an average particle size from 10 to 100 μm and an aspect ratio from 1 to 1.5. Semiconductor devices

according to this invention are characterized in that a semiconductor chip therein is bonded to the mounting component for the chip by the aforementioned adhesive.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross section of an integrated circuit that is an example of a semiconductor device according to the present invention.

Figure 2 is a cross section of an integrated circuit that is also an example of a semiconductor device according to the present invention.

Reference Numbers

1	semiconductor chip
2	semiconductor chip mounting component
3	adhesive
4	conductor
5	lead
6	sealant/adhesive
7	solder ball
8	frame
9	bump

DESCRIPTION OF INVENTION

The present invention is an adhesive for bonding a semiconductor chip to an attachment member for the chip comprising a curable polymer composition comprising

from 1 to 900 weight-ppm spherical filler having an average particle size of from 10 to 100 μm and a major axis-to-minor axis ratio of from 1 to 1.5 The present invention is also semiconductor devices characterized in that a semiconductor chip is bonded to a mounting component thereof by the aforementioned adhesive.

The adhesive of this invention will be described in detail first. The spherical filler in this adhesive is the component for effecting bonding between the semiconductor chip and its mounting component across a constant gap. The average particle size of this spherical filler should be between 10 and 100 μm. The basis for this range is as follows. The generation of a constant gap between the semiconductor chip and its mounting component becomes highly problematic in the case of adhesive that uses spherical filler with an average particle size below 10 μm. At the other extreme, the use of spherical filler with an average particle size exceeding 100 μm is undesirable when the generation of an overly large chip-to-mounting component gap is undesirable. The aspect ratio of the spherical filler under consideration should be within the range from 1 to 1.5 and is preferably from 1.0 to 1.1. It becomes increasingly difficult to generate a constant chip-to-mounting component gap in the case of adhesive that uses spherical filler whose aspect ratio exceeds the given upper limit. In a particularly preferred embodiment, the standard deviation on the particle size distribution of the spherical filler does not exceed 10% of the average particle size of the filler.

The spherical filler under consideration is exemplified by inorganic spherical fillers composed of silica, glass, alumina, aluminosilicate, silicon nitride, boron nitride,

silicon carbide, carbon, titanium oxide, aluminum, alumite, copper, silver, and stainless steel; and by organic spherical fillers composed of carbon, fluororesin, silicone resin, silicone rubber, epoxy resin, polyimide resin, polyphenylene sulfide resin, and polyetheretherketone resin. The spherical filler can be hollow or can be porous with pores on the surface and/or in the interior. Inorganic spherical fillers are preferred.

The spherical filler content in the adhesive under consideration should be from 1 to 900 weight-ppm and preferably is from 1 to 800 weight-ppm and more preferably is from 1 to 700 weight-ppm, in each case based on the weight of the curable polymer composition. It becomes increasingly difficult to obtain a constant chip-to-mounting component gap when the spherical filler content in the adhesive falls below the above-specified lower limit. At the other extreme, an inability to thoroughly relax the mechanical stresses acting on the semiconductor chip becomes increasingly prominent when the above-specified upper limit is exceeded. In addition, in a preferred embodiment, the spherical filler is present in the adhesive in an amount that avoids a stacking or superimposition of neighboring spherical filler particles one above the other in the space between the semiconductor chip and its mounting component. For example, the spherical filler is preferably present in an amount such that the spherical filler particle count per the coated area is at least 3 and no more than {coated area/(particle size of the spherical filler)^2} × 0.9. When the spherical filler content in the adhesive provides a spherical filler particle count per the coated area of less than 3 or more than {coated area/(particle size of the spherical filler)^2} × 0.9 in which case neighboring particles of

the spherical filler will overlap each other, it will become increasingly difficult to obtain a constant gap between the semiconductor chip and its mounting component.

The curable polymer composition used in the present adhesive composition is exemplified by curable epoxy resin compositions, curable silicone compositions, curable acrylic resin compositions, and curable polyimide resin compositions. The curable epoxy resin compositions are exemplified by curable epoxy resin compositions and curable silicone-modified epoxy resin compositions; the curable silicone compositions are exemplified by curable silicone compositions, curable epoxy-modified silicone compositions, curable acrylic-modified silicone compositions, and curable polyimide-modified silicone compositions; the curable acrylic resin compositions are exemplified by curable acrylic resin compositions and curable silicone-modified acrylic resin compositions; and the curable polyimide resin compositions are exemplified by curable polyimide resin compositions and curable silicone-modified polyimide resin compositions. Curable epoxy resin compositions and curable silicone compositions are preferred. In a particularly preferred embodiment, the curable polymer composition is a curable silicone composition due to the ability of curable silicone compositions to thoroughly relax the mechanical stresses acting on semiconductor chips and also due to the excellent heat resistance of curable silicone compositions. The curable silicone compositions are exemplified by those curable by condensation reactions, those curable by addition reaction, those curable by ultraviolet radiation, and those curable by organoperoxide-mediated radical reactions, with addition reaction-curable silicone compositions being preferred. The addition reaction-curable silicone compositions can

comprise, for example, (A) organopolysiloxane having at least 2 alkenyl groups in each molecule, (B) organopolysiloxane having at least 2 silicon-bonded hydrogen atoms in each molecule, (C) an organosilicon compound having Si-bonded alkoxy, and (D) a platinum catalyst.

The organopolysiloxane (A), which is the base component in such an addition reaction-curable silicone composition, must contain at least 2 alkenyl groups in each molecule. This alkenyl is exemplified by vinyl, allyl, butenyl, pentenyl, hexenyl, and heptenyl with vinyl being preferred. The non-alkenyl silicon-bonded groups in (A) are exemplified by monovalent hydrocarbon groups excluding alkenyl, for example, alkyl groups such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, and octyl; aryl groups such as phenyl, tolyl, and xylyl; aralkyl groups such as benzyl and phenethyl; and halogenated alkyl groups such as 3-chloropropyl and 3,3,3-trifluoropropyl. Methyl and phenyl are preferred for the non-alkenyl silicon-bonded groups. The proportion of phenyl of the total silicon-bonded organic groups in (A) is preferably in the range of from 1 to 30 mole% because this affords a composition with excellent cold resistance. Component (A) can be, for example, a single polymer having a straight-chain, partially branched straight-chain, branched-chain, cyclic, or resin-like molecular structure or can be a mixture of polymers with such molecular structures. Component (A) preferably has a viscosity at 25°C in the range of from 10 to 1,000,000 mPa·s.

The organopolysiloxane (B) is a crosslinker for the addition reaction-curable silicone composition and must contain at least 2 silicon-bonded hydrogen atoms in each molecule. The silicon-bonded groups in (B) other than hydrogen are exemplified by

monovalent hydrocarbon groups, for example, alkyl groups such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, and octyl; aryl groups such as phenyl, tolyl, and xylyl; aralkyl groups such as benzyl and phenethyl; and halogenated alkyl groups such as 3-chloropropyl and 3,3,3-trifluoropropyl. Methyl and phenyl are preferred for the non-hydrogen silicon-bonded groups. Component (B) can be, for example, a single polymer having a straight-chain, partially branched straight-chain, branched-chain, cyclic, or resin-like molecular structure or can be a mixture of polymers with such molecular structures. Component (B) preferably has a viscosity at 25°C in the range of from 1 to 10,000 mPa·s.

The the addition reaction-curable silicone composition composition preferably contains component (B) in an amount that provides from 0.3 to 10 moles silicon-bonded hydrogen from (B) per mole alkenyl in (A). The composition will not undergo a satisfactory cure when the addition of component (B) provides less silicon-bonded hydrogen per mole alkenyl in (A) than the lower limit of the given range. When the addition of (B) provides more silicon-bonded hydrogen per mole alkenyl in (A) than the upper limit of the given range, the cured product will exhibit diminished mechanical strength.

The organosilicon compound (C) functions to improve the adherence of the addition reaction-curable silicone composition and must contain at least 1 silicon-bonded alkoxy group in the molecule and preferably contains at least 3 silicon-bonded alkoxy groups in the molecule. The alkoxy in (C) can be, for example, methoxy, ethoxy, propoxy, or butoxy with methoxy being preferred. The other silicon-bonded groups in (C) can be exemplified by the hydrogen atom; the hydroxyl group; functional organic

groups such as 3-glycidoxypropyl, 2-(3,4-epoxycyclohexyl)ethyl, and 3-methacryloxypropyl; and monovalent hydrocarbon groups, for example, alkyl groups such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, and octyl; alkenyl groups such as vinyl, allyl, butenyl, pentenyl, and hexenyl; aryl groups such as phenyl, tolyl, and xylyl; aralkyl groups such as benzyl and phenethyl; and halogenated alkyl groups such as 3-chloropropyl and 3,3,3-trifluoropropyl. Component (C) preferably contains the vinyl group, silicon-bonded hydrogen, or an epoxy-functional organic group such as 3-glycidoxypropyl or 2-(3,4-epoxycyclohexyl)ethyl.

Component (C) can be exemplified by 3-glycidoxypropyltrimethoxysilane; 3-glycidoxypropyltriethoxysilane; 2-(3,4-epoxycyclohexyl)ethyltrimethoxysilane; vinyltrimethoxysilane; organosiloxane oligomer whose molecule contains silicon-bonded alkoxy, SiH, and 3-glycidoxypropyl or 2-(3,4-epoxycyclohexyl)ethyl; and organosiloxane oligomer whose molecule contains silicon-bonded alkoxy, silicon-bonded alkenyl, and 3-glycidoxypropyl or 2-(3,4-epoxycyclohexyl)ethyl.

The addition reaction-curable silicone should contain from 0 to 20 weight parts component (C) per 100 weight parts component (A). A composition containing component (C) in excess of the upper limit of the given range will give a cured product with diminished mechanical strength.

The platinum catalyst (D) is for inducing the addition reaction-mediated cure of the addition reaction-curable silicone composition. Component (D) is exemplified by platinum black, platinum supported on silica micropowder, platinum supported on active carbon, platinum supported on alumina powder, chloroplatinic acid, alcohol solutions of

chloroplatinic acid, olefin complexes of platinum, alkenylsiloxane complexes of platinum, carbonyl complexes of platinum, and thermoplastic resin powder with an average particle size ≤ 10 μm that contains one or more of the previously listed platinum catalysts. The thermoplastic resin in the last-named example can be polystyrene resin, nylon resin, polycarbonate resin, silicone resin, and so forth.

Component (D) should be added to the addition reaction-curable silicone composition in sufficient quantity to induce the cure of the composition. In specific terms, component (D) is preferably added to the composition in an amount that provides from 1 to 1,000 weight-ppm platinum metal.

The addition reaction-curable silicone composition preferably contains an addition-reaction inhibitor as an optional component. This addition-reaction inhibitor is exemplified by alkyne alcohols such as 3-methyl-1-butyn-3-ol, 3,5-dimethyl-1-hexyn-3-ol, and 3-phenyl-1-butyn-3-ol; ene-yne compounds such as 3-methyl-3-penten-1-yne and 3,5-dimethyl-3-hexen-1-yne; and by 1,3,5,7-tetramethyl-1,3,5,7-tetravinylcyclotetrasiloxane, 1,3,5,7-tetramethyl-1,3,5,7-tetrahexenylcyclotetrasiloxane, and benzotriazole. The composition preferably contains from 10 to 50,000 weight-ppm addition-reaction inhibitor.

The present adhesive composition can contain, as an optional component, an organic resin powder, metal powder, or inorganic powder, in each case with an average particle size no greater than 100 μm. The organic resin powder can be composed of, for example, a fluororesin or silicone resin; the metal powder can be composed of, for example, silver, nickel, or copper; and the inorganic powder can be, for example, silica,

titanium oxide, carbon black, alumina, quartz powder, and glass. More particularly, adhesive compositions containing inorganic powder with a specific surface area of 50 to 500 m^2/g are thixotropic and inhibited the sedimentation and separation of the previously described spherical filler. The present adhesive composition can also contain, for example, heat stabilizer, flame retardant, colorant, and organic solvent.

The present adhesive composition can be, for example, a relatively low viscosity fluid, a relatively high viscosity fluid, a grease, or a paste. The present adhesive composition can be applied by using an ejector- or extruder-type device such as a dispenser. In addition, the present adhesive composition can be formed in a sheet or film configuration by partially crosslinking the adhesive or, when the curable polymer composition takes the form of a hot-melt adhesive, by converting the composition to a sheet or film.

The present adhesive composition preferably cures to give a rubber or gel. The adhesive can be cured at room temperature or by heating. In the case of heating, the adhesive composition is preferably heated, for example, to 50 to 200°C using a heating lamp, hot plate, heated block, or forced hot-air convection oven.

Semiconductor devices according to this invention will now be considered in detail. The characteristic feature of a semiconductor device according to this invention is that a semiconductor chip therein is bonded to its chip mounting component by the hereinabove-described adhesive. The semiconductor device can be, for example, an integrated circuit, LSI device, or VLSI device. Semiconductor devices according to this

invention will be explained in detail with reference to the drawings appended herewith. In the semiconductor device shown in Figure 1, a semiconductor chip **1** is bonded to a semiconductor chip mounting component **2** (a chip carrier in Figure 1) by adhesive **3**. In this case the semiconductor chip **1** is bonded facing the semiconductor chip mounting component **2**. Conductors **4** are formed on the surface of the semiconductor chip mounting component **2** that faces the semiconductor chip **1**. The conductors **4** and the semiconductor chip **1** are electrically connected by leads **5**. The leads **5** are sealed or packed, in their entirety or partially, by a sealant/filler **6**. The semiconductor chip mounting component **2** in the semiconductor device shown in Figure 1 has been provided with solder balls **7** to enable mounting of the semiconductor device on a substrate. The semiconductor device in Figure 1 has also been provided with a frame **8** in order to protect the semiconductor chip **1** from external mechanical stresses. This frame **8** is an optional feature for semiconductor devices according to this invention.

In the semiconductor device shown in Figure 2, a semiconductor chip **1** is bonded to a semiconductor chip mounting component **2** (a circuit substrate in Figure 2) by adhesive **3**. In this case, again, the semiconductor chip **1** is bonded facing the semiconductor chip mounting component **2**. Conductors **4** are formed on the surface of the semiconductor chip mounting component **2** that faces the semiconductor chip **1**. The conductors **4** and the semiconductor chip **1** are electrically connected by bumps **9**. These bumps **9** are sealed or packed, in their entirety or partially, by a sealant/filler **6**. In order to mount the semiconductor device in Figure 2 on a substrate, leads are provided that

electrically connect with the conductors 4. Although not shown in Figure 2, the semiconductor chip 1 may be sealed with a resin sealant.

Neither the semiconductor chip nor the semiconductor chip mounting component are critical for semiconductor devices of this invention. The semiconductor chip mounting component can be, for example, a ceramic-type chip mounting component for example an alumina or glass component; an organic resin-type chip mounting component for example an epoxy resin, glass fiber-reinforced epoxy resin, polyimide resin, or bismaleimide triazine resin component; or a metal-type chip mounting component, for example a stainless steel or copper component, and can be, for example, a rigid circuit substrate or chip carrier or a flexible circuit substrate or chip carrier. The conductors can be formed on the surface or in the interior of the semiconductor chip mounting component by such means as printing, vapor deposition, gluing, lamination, plating, and so forth. Outer connecting terminals such as a ball grid (e.g., solder balls) or pin grid and other electrical elements or components may also be provided or mounted. The component that electrically connects the semiconductor chip with the conductors of the semiconductor chip mounting component can be, for example, bonding wires, leads, or bumps. In order to relax the stresses acting on such components when the semiconductor device is subjected to thermal shock in their bonding wire and lead implementations these components are preferably curved or bent and in their bump embodiments are preferably made of a material with a small Young's modulus.

The use of a sealant/filler is preferred for the purpose of improving the reliability of semiconductor devices according to this invention. The sealant/filler is exemplified by

epoxy resin sealant/fillers such as epoxy resin sealant/fillers and silicone-modified epoxy resin sealant/fillers; silicone sealant/fillers such as silicone sealant/fillers, epoxy-modified silicone sealant/fillers, acrylic-modified silicone sealant/fillers, and polyimide-modified silicone sealant/fillers; acrylic resin sealant/fillers such as acrylic resin sealant/fillers and silicone-modified acrylic resin sealant/fillers; and polyimide resin sealant/fillers such as polyimide resin sealant/fillers and silicone-modified polyimide resin sealant/fillers. Silicone sealant/fillers are preferred. In order to effect sealing or packing of the component that electrically connects the semiconductor chip with the conductors on/in the corresponding chip mounting component, the sealant/filler is preferably a paste or liquid with liquids being particularly preferred. With regard to the procedure for sealing or packing the aforesaid electrically connecting component with the sealant/filler, the sealant/filler may be cured, for example, by heating with a hot gas current or thermal radiation, or can be brought into contact with moisture, or can be exposed to ultraviolet radiation or an electron beam. In the case of semiconductor devices of this invention, a preferred approach for sealing or packing with the sealant/filler composition comprises the cure of a thermosetting sealant/filler by heating. This sealant/filler is preferably a sealant/filler that upon the application of heat thereto forms a cured product that is a gel or rubber at ambient temperature.

The particular process for fabricating semiconductor devices according to the present invention is not critical. As an example of a process by which the semiconductor device in Figure 1 can be fabricated, the semiconductor chip 1 and the semiconductor chip mounting component 2 can first be attached together facing each other using the

above-described adhesive; the adhesive can then be cured; and the semiconductor chip 1 and the conductors 4 of the semiconductor chip mounting component 2 can thereafter be electrically connected by the leads 5. This electrical connection can, however, also be effected prior to adhesive cure. In addition, these leads 5 can be sealed or packed, in their entirety or partially, with a sealant/filler and the sealant/filler can then be cured. As an example of a process by which the semiconductor device in Figure 2 can be fabricated, the semiconductor chip 1 and the semiconductor chip mounting component 2 can first be attached together facing each other using the above-described adhesive; the adhesive can then be cured; and the semiconductor chip 1 and the conductors 4 of the semiconductor chip mounting component 2 can thereafter be electrically connected by the bumps 9. Again, this electrical connection can also be effected prior to adhesive cure. These bumps 9 can also be sealed or packed, in their entirety or partially, with a sealant/filler and the sealant/filler can then be cured. A frame can be used for the purpose of preventing sealant/adhesive outflow during this step. A metal or plastic frame can be used for this purpose, but the frame can also be formed from a curable, thixotropic liquid-form or grease-form organic resin composition. A frame having the form of a rubber or gel is particularly preferred.

Examples

The present adhesive compositions and semiconductor devices are explained in greater detail below through working examples. The viscosity values reported in the examples were measured at 25°C using a rotational viscometer (single cylinder geometry,

Vismetron V from Shibaura System Co.). The procedure for fabricating the semiconductor devices and the evaluation methodologies are described below.

Semiconductor device fabrication

Semiconductor devices as shown in Figure 2 were fabricated as follows. The adhesive was coated on a circuit substrate and the semiconductor chip (area = 50 mm^2) was then applied onto the adhesive. The semiconductor chip was then bonded onto the circuit substrate by curing for 30 minutes at 150°C while pressing with a hot-press bonder. The semiconductor chip and the conductors formed on the circuit substrate were subsequently electrically connected by bumps. Finally, the bumps were completely vacuum impregnated at 10 torr with a thermosetting silicone sealant/filler followed by cure of the sealant/filler by heating for 30 minutes at 150°C. Twenty semiconductor devices were fabricated by this procedure.

Measurement of the film thickness of the adhesive layer in the semiconductor devices

The average thickness, minimum thickness, and maximum thickness of the adhesive layer were measured on 20 semiconductor devices by subtracting the thickness of the semiconductor chip and its mounting component (the thickness of the semiconductor chip and its mounting component were measured in advance) from the overall thickness of the semiconductor device.

Measurement of the spherical filler count in the adhesive layer of the semiconductor devices

The spherical filler particle count per the coated area was determined by inspecting the adhesive-coated side with a microscope.

Semiconductor device reliability testing

Each semiconductor device was subjected to thermal cycle testing with one cycle consisting of holding for 30 minutes at −55°C and holding for 30 minutes at +150°C. Using the terminals of the conductors on the semiconductor device, electrical continuity testing was carried out after 1,000 cycles and after 3,000 cycles. The defect rate was determined from the number of devices that exhibited defective continuity.

Example 1. An adhesive with a viscosity of 7,000 mPa·s was prepared by mixing the following to homogeneity: 100 weight parts dimethylvinylsiloxy-endblocked dimethylpolysiloxane with a viscosity of 2,000 mPa·s and a vinyl content of 0.23 weight%, 1.5 weight parts trimethylsiloxy-endblocked methylhydrogenpolysiloxane with a viscosity of 20 mPa·s and a silicon-bonded hydrogen content of 1.6 weight%, 1weight part organopolysiloxane with the average unit formula

$$((CH_2{=}CH)CH_3SiO_{2/2})_{0.50}(CH_3O_{1/2})_{0.33}(\underset{\diagdown\ \mathrm{O}\ \diagup}{CH_2{-}CH}CH_2OC_3H_6SiO_{3/2})_{0.17},$$

0.1 weight part of a 1 weight% isopropanolic chloroplatinic acid solution, 0.05 weight part (this addition gave 500 weight-ppm in the adhesive) of a spherical silica micropowder with an average particle size of 40 μm (standard deviation on the particle size distribution = 3 μm) and an aspect ratio of 1.05, 0.01 weight part 3-phenyl-1-butyn-

3-ol, and 2 weight parts fumed silica (average particle size = 30 mμ, BET specific surface area = 200 m^2/g) whose surface had been treated with hexamethyldisilazane. When heated for 30 minutes at 150°C, this adhesive produced a silicone rubber that gave a value of 30 for the type A durometer specified in JIS K-6253. Semiconductor devices were fabricated using the adhesive, and the results of evaluation of these semiconductor devices are reported in Table 1.

Comparative Example 1. An adhesive with a viscosity of 6,500 mPa·s was prepared as in Example 1, but in this case omitting the spherical silica micropowder (average particle size = 40 μm, standard deviation on the particle size distribution = 3 μm, aspect ratio = 1.05) that was used in Example 1. When heated for 30 minutes at 150°C, this adhesive produced a silicone rubber that gave a value of 28 for the type A durometer specified in JIS K-6253. Semiconductor devices were fabricated using the adhesive, and the results of evaluation of these semiconductor devices are reported in Table 1.

Comparative Example 2. An adhesive with a viscosity of 12,500 mPa·s was prepared as in Example 1, but in this case using 157 weight parts (this addition corresponded to 60 weight% in the adhesive) of the spherical silica micropowder (average particle size = 40 μm, standard deviation on the particle size distribution = 3 μm, and aspect ratio = 1.05) that was employed in Example 1. When heated for 30 minutes at 150°C, this adhesive produced a silicone rubber that gave a value of 48 for the type A durometer specified in JIS K-6253. Semiconductor devices were fabricated using the

adhesive, and the results of evaluation of these semiconductor devices are reported in Table 1.

Comparative Example 3. An adhesive with a viscosity of 7,000 mPa·s was prepared as in Example 1, but in this case replacing the spherical silica micropowder (average particle size = 40 μm, standard deviation on the particle size distribution = 3 μm, aspect ratio = 1.05) that was used in Example 1 with an equal amount of silica micropowder that had an average particle size of 40 μm, an aspect ratio of 2.0, and a standard deviation on the particle size distribution of 15 μm. When heated for 30 minutes at 150°C, this adhesive produced a silicone rubber that gave a value of 28 for the type A durometer specified in JIS K-6253. Semiconductor devices were fabricated using the adhesive, and the results of evaluation of these semiconductor devices are reported in Table 1.

Example 2. An adhesive with a viscosity of 21,000 mPa·s was prepared by mixing 100 weight parts of a thermosetting epoxy resin composition with a viscosity of 20,000 mPa·s (TXEP-100 from Dow Corning Toray Silicone Company, Limited, containing 50 weight% spherical silica powder with an average particle size of 2 μm and a maximum particle size of 8 μm) to homogeneity with 0.05 weight part (this addition gave 500 weight-ppm in the adhesive) spherical silica micropowder with an average particle size of 40 μm, aspect ratio of 1.05, and standard deviation on the particle size distribution of 3 μm. When heated for 2 hours at 150°C, this adhesive produced a cured epoxy resin that gave a value in excess of 95 for the type A durometer specified in JIS K-

6253. Semiconductor devices were fabricated using the adhesive, and the results of evaluation of these semiconductor devices are reported in Table 1.

Table 1.

	Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3
thickness of the adhesive layer (µm)					
average value	48	49	34	80	55
maximum value	50	50	41	98	72
minimum value	43	45	19	55	47
spherical filler count	16	17	0	48000	17
semiconductor device defect rate (%)					
1,000 cycles	0	0	15	35	5
3,000 cycles	0	0	35	55	10